A SUPPLEMENT TO Geometrical Dialling,

By *WILLIAM LEYBOURN*, Philomath.

SHEWING

How by Scale and Compaſſes to inſcribe ſuch Circles of the *Sphere* into Sun-Dial-Plains, that ſhall ſhew (beſides the Hour of the Day) the Diurnal Motion of the Sun; his Place in the *Zodiack*; the Time from his Riſing, and Setting; the *Babylonian*, *Italian*, and *Jewiſh* Hours; the Point of the Compaſs upon which the Sun is at any time of the Day, and the Proportions of Shadows to their Heights.

ALSO

A General and Eaſie way to project Hour-Lines upon all kinds of Superficies, without any regard had to their ſtanding, either in reſpect of Declination, Reclination, or Inclination.

AND

How from a Glaſs *Horizontally* placed in the Soyl of a Window, to reflect Hours upon any Superficies, either Flat, or Curved; one, or many.

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A SUPPLEMENT TO Geometrical Dialling, &c.

CHAP. I.

Of ſuch Circles *of the* Sphere, *as are deſcribed upon* Sun-Dials.

MAny *Aſtronomical* Concluſions may be performed by deſcribing of the *Circles* of the *Sphere* upon *Dial-Plains*; of which I have here made choice of theſe following:

1. The *Parallels* of the *Signs*, ſhewing in what part of the *Zodiack* the Sun is at all times of the year.

2. The *Diurnal Arches*, ſhewing the length of the *day* and *night* throughout the *year*.

3. The *Hours* from the *Sun's Riſing*, or *Setting*; or the *Babyloniſh* and *Italian Hours*.

4. The *Unequal*, *Jewiſh*, or *Planitary* hours.

5. The *Azimuths*, or *Vertical Circles*, ſhewing in what quarter of the *World*, or upon what *Point* of the *Mariners Compaſs*, the Sun is at all times of the Day.

6. The *Almicanters*, or *Circles* of *Altitude*; whereby the *Proportion* of *Shadows* to their *Objects*, or the *Sun's height* may be known.

Of these some are *great Circles* of the *Sphere*, others *small*: The *great Circles* in all Plains are represented by *streight lines*, as the *hour-lines* themselves are: The *lesser Circles* are described by *Conick Sections*; and they are either *Parabolas*, *Hyperbolas*, or *Ellipses*: Only the *Parallels* of the *Signs*, and the *Diurnal Arches* in *Polar Dials*, and the *Parallels* of *Altitude* in *Horizontal Dials*, and perfect Circles.

CHAP. II.

How to describe the Equinoctial, *the two* Tropicks, *and other intermediate* Parallels *of* Declination, *upon any Dial Plain.*

THe two *Tropicks* being the Boundaries of the *Sun's Course*, (for he never exceeds those Limits,) I count it best, first to shew how they may be described; for that between them all other *Circles* (either *great* or *small*) must be *projected*, and the manner of describing them upon several Plains is various.

In a *Polar Dial* they are perfect *Circles*, and so are easily described by *Circles* drawn about the foot of the *perpendicular stile*; in all other Plains they are *Sections* of a *Cone*.

I. *In the* Equinoctial, *and direct* East *or* West *Dials.*

Let an Example be of a direct *East Dial* in the Latitude of 51 *d.* 32 *m.*

How to describe the *hour-lines* upon these Plains is shewed in the sixth Chapter of this Book. Wherefore such a Dial

a Dial being drawn as in Figure I. through the *foot* of the *perpendicular ſtile* at E, draw a right Line M E N, *Parallel* to the *Horizon*; for the *Horizontal Line*, in all Plains, muſt be drawn through the foot of the *perpendicular ſtile*, and alſo through the Point where the *Equinoctial Circle* croſſeth the *Hour-Line* of *Six*. Your Dial, with the *Equinoctial* Line thereof, H E S, being drawn, come we to deſcribe the *Tropicks*: To effect which,

Firſt, Upon a piece of fine *Card-Paiſt-Board* draw a right Line O R, as in Figure II. repreſenting the *Equinoctial* Line in your Dial; and (becauſe the *Tropicks* are 23 deg. 30 min. diſtant from the *Equinoctial*) with 60 deg. of your *Chords*, upon the point O, deſcribe an Arch of a Circle, and upon it ſet 23 deg. 30 min. from R to S, and draw the Line O S, repreſenting the two *Tropicks*; and this Angle S O R, I call a *Trigon*.

Secondly, Out of your Dial take the length of the *perpendicular Stile* E G, and ſet it upon the *Trigon* from O to P, and draw the Line P 6 perpendicular to O R: Alſo

Take the diſtance from G, to the Interſection of the Hour-Line of	7 8 9 10 11	with the Equinoctial, and ſet them upon the Trigon from O, to	*q r s t v*	and draw the Lines	*q r s t v*	7 8 9 10 11	perpendicular to O R.

Having thus prepared the *Trigon*, out of it take the diſtance P 6, and ſet it upon the 6 a clock *hour-line*, from E to *c*: —— Alſo take the diſtance *q* 7, and ſet it upon your Plain from V to *b*, and from VII to *d*: —— Alſo take *r s*, and ſet it on your Plain from IV to *a*, and from VIII to *e*: —— Likewiſe take the diſtance *s* 9, and ſet it upon your Plain from IX to *f*: —— Alſo take the diſtance 10 *t*, and ſet it from X to *g* — Laſtly, take *v* 11, and ſet it on the Plain from XI to *h*.

These Points *a, b, c, d, e, f, g, h,* are the Points through which the *Tropick of Cancer* must be described; wherefore, if through them a line be drawn with an even hand, making no Angles, that shall be the *Tropick* of *Cancer.*

The *Tropick* of *Capricorn* may be described in the same manner, for if from your *Trigon* you take

The distance	8	*r*	And set it upon your *Dial-Plain* from	VIII	*k*
	9	*s*		IX	*l*
	10	*t*		X	*m*
	11	*v*		XI	*n*

Those shall be the Points through which the *Tropick* of *Capricorn* must be described; wherefore if through *k l m n,* a line be drawn with an even hand, it shall represent the *Tropick* of *Capricorn*:

And whereas I said before, that the two *Tropicks* are the Boundaries of the *Sun's Course,* you are to Note, That

When the Sun is in	*Capricorn,*	which is about	*Decem.* 11.	the shadow of the top of the *Stile* will pass along those respective Lines.
	Aries, or *Libra,*		*March,* 10.	
			Sept. 12.	
	Cancer,		*June,* 11.	

And according to this Method may any other intermediate *Parallels* of *Declination* be inserted; as for *Example*: Suppose I would insert the *Parallels* of the *Sun's* entrance into the 12 *Signs, Aries* and *Libra* are inserted already, also *Cancer* and *Capricorn*; for the rest, as when the Sun enters into

Taurus,

Taurus, *Virgo*, *Scorpio*, *Piſces*, } the Sun hath 11 deg. 30 min. }
Gemini, *Leo*, *Sagittarius*, *Aquarius*, } the Sun hath 20 deg. 12 min. } of Declination,

Wherefore take 11 deg. 30 min. and 20 deg. 12 min. out of your Line of Chords, and ſet them upon Arch R S of your *Trigon*, from R to V and X, and draw the two Lines O U and O X.

Theſe *Parallels* being thus put into your *Trigon*, they may be transferred into the *Dial Plain*, in all reſpects, as the *Tropicks* were; and as you ſee done in the Figure I.

II. *In a* Direct North *or* South *Dial.* Figure III.

Having drawn your *Dial* as is taught in Chapter V. together with the *Stile*, your firſt work muſt be to *proportion your Stile to your Plain*; which to doe, aſſume any convenient point in the *Subſtile* (here the Line of XII) for the farthermoſt *Tropick*, as here the Point ♋; then the *Stile's* height being 38 deg. 28 min. add 23 deg. 32 min. thereto, the Summ is 62 deg. and that isthe *Meridian Altitude* of the *Sun* when he enters *Cancer*, and the Complement thereof is 28 deg. wherefore, upon the Point *Cancer*, make an Angle B ♋ A to contain 28 deg. ſo ſhall the Line ♋ A cut the *Axis* of the *Stile* O A, in A; then from A let fall a Perpendicular to O ♋, as A B; and ſo is your *Stile* proportioned to your *Plain*; and the Line C B D, (being drawn *Parallel* to the *Horizon*, through the Point B,) ſhall be the *Horizontal Line* of the *Plain*.

This

This done, prepare a *Trigon*, as Figure IV. in which make E F equal to O A, and F G equal to O B, and E G, to A B, the *Triangle* E F G in the *Trigon*, equal to the *Triangle* of the *Stile* O A B in the *Dial*.

From the Point E draw a Perpendicular to E F, as E 12, for the *Equinoctial*; and upon E, with 60 deg. of your *Chord* deſcribe an Arch H 12 L, and upon it ſet 23 deg. 30 min. from 12 to H and L, 4 drawing the Line E H for the *Tropick* of *Cancer*, and E L for the *Tropick* of *Capricorn*:

Draw the *Subſtilar* Line F G quite through the *Trigon*, croſſing the *Equinoctial* in *a*, and both the *Tropicks*.

This done, out of your *Trigon* take the diſtance from F to *a*, and ſet it upon the *Dial plain* from the *Center* O to *c*, through which Point *c* draw the right Line ♈ *c* ♎ for the *Equinoctial*: Then from O, the Center of your *Dial*, take the diſtance to the interſection of the *Hour-Line* of 11 or 1 with the *Equinoctial*, and ſet that diſtance upon the *Trigon* from F to *b*: — Alſo take the diſtance from O, to the interſection of the Hour-Line of 10 or 2, and ſet it from F to *c*: —— Likewiſe the diſtance from O, to the interſection of the Hour-Line of 9 or 3, ſet from E to *d*: —— And laſtly, the diſtance from O, to the interſection of 8 or 4, with the *Equinoctial*, ſet from F to *e*; and draw the Lines F *a*, F *b*, F *c*, F *d*, F *e*, through the *Trigon*, marking them with 12, 11, 10, 9, 8 and 1, 2, 3, 4, &c.

Now to find the Points upon the *Plain*, through which the *Tropicks* muſt paſs;

The Diſtance from F to	12	will reach from O, the Center of the *Dial*, to	♋	on the Hour-Lines of	12		
	11		*f*		11		1
	10		*g*		10		2
	9		*h*		9		3
	8						

Through

Through which points the *Tropick* of *Cancer* muſt be drawn with an even hand: And,

The diſtance from F to	12	will reach from O, the *Center* of the *Dial*, to	♍	*k*	upon the Hour-lines of	12	12
	1			*l*		11	1
	2			*m*		10	2
	3			♎		9	3
	4					8	4

Through which Points the *Tropick* of *Capricorn* muſt be drawn. And thus have you the *Equinoctial*, and the two *Tropicks*, deſcribed upon a direct South Plain.

III. *How to deſcribe the* Equinoctial, *and the two* Tropicks *into any* Upright Declining Plain; *or into ſuch as both* Recline *and* Decline.

Our *Example* ſhall be in an *Upright Plain*, declining from the *South Weſtward* 30 deg. The making of theſe Dials is taught in the VII. and VIII. Chapters of this Book: Wherefore, having drawn ſuch a *Dial*, with the *Stile* and *Subſtile* in a due *Poſition*, you ſhall find the height of the *Stile* to be 32 deg. 36 min.

Firſt, Make an *Horizontal Dial* for the Latitude of 32 deg. 36 min. as is the *Declining Dial* Fig. V, where the *Subſtilar Line* is taken for the Hour-Line of 12, as it is there marked, and the other Pricked-Lines, and the Hour-Lines of an *Horizontal Dial* for the Latitude of 32 deg. 36 min. Now, if according to the directions of the foregoing *Section*, you make a *Trigon*, and inſert the *Equinoctial* and *Tropicks*; and afterwards expunge the obſcure Lines of the *Horizontal Dial*, the *Equinoctial*, *Tropicks*, and *Horizontal Line* will be the ſame, as if they had been inſerted from the true Hour-Lines belonging to the Plain.

And as the *Tropicks* were deſcribed, ſo likewiſe may the *Parallels* of the Sun's Entrance into the other Signs, be inſerted, if into your *Trigon* you put the *Arches* of their *Declinations* from the *Equinoctial*, namely 11 deg. 30 min. and 20 deg. 12 min. And ſo are the *Parallels* of the *Signs* put into this *Dial*, Fig. V——

And in any *Dial* alſo may the *Diurnal Arches* be deſcribed, if you put into the *Trigon* ſuch *Declinations* as the Sun hath from the *Equinoctial*, when the Day is either

♈		♎		deg.	min.
8		16	Hours long, as	23	30
9	or	15		21	40
10		14		16	55
11		13		11	37
12		12		5	55
				00	00

And ſo are the *Diurnal Arches* put into the South-Plain, repreſented by the Pricked lines there, in Fig. III, and the *Trigon* thereunto belonging Fig. IV.

CHAP. III.

How the Hours *from the* Sun's Riſing *and* Setting *are to be inſcribed into all ſorts of* Dial-Plains.

THe *Hours* from *Sun-Riſing* are called the *Babyloniſh Hours*, for that they begin their Day at the *Sun's Riſing*; and the *hours* from *Sun-Setting* are called the *Italian hours*, for that in *Italy* they account their *Time* from the *Setting* of the *Sun* the day preceding.

The manner how to inſcribe theſe *hours*, is the ſame in all Plains, and is eaſily performed: And becauſe that upon

on a full *South*, or *Horizontal Plain*, they will appear moſt uniform; I have therefore made choice of a direct *South Dial*, as is Fig. III. to inſcribe them:

Your *Dial* being drawn, and the *Equinoctial*, ♈ ♎, the two *Tropicks*, and ♋ ♋, and ♑ ♑, and the *Horizontal-Line*, *Sun Riſe*, *Sun Set*; you muſt (by the laſt Chapter) deſcribe two obſcure *Parallels* of *Declination*, one when the Day is 8 hours long, as ☉ 8 ☉, and the other when the Day is 16 hours long, as ✱ 16 ✱, the *Equinoctial* being the *Parallel* when the Day is 12 hours long.

Being thus far prepared, the inſcription of theſe *hours* will be very eaſie; for it is plain, that when the day is but 8 hours long, that the *Sun riſes* at 8 in the Morning; and the firſt line after the *Sun's Riſing* is 9 in the Morning; —— Alſo when the day is 12 hours long, the *Sun Riſes* at 6 in the Morning, and the firſt hour after is 7 in the Morning; —— Laſtly, When the Day is 16 hours long, the *Sun riſes* at 4 in the Morning, and the next hour after is 5 in the Morning: —— And all the reſt as in this Table. Wherefore, a ſtreight line drawn through the interſections of theſe hour-lines, with the *Parallels* of 8, 12 and 16 hours, ſhall be the firſt hour after the *Sun Riſing* all the year long.

Hours from Sun Riſing	*Length of the Day.* VIII	XII	XVI
I	9	7	5
II	10	8	6
III	11	9	7
IV	12	10	8
V	1	11	9
VI	2	12	10
VII	3	1	11
VIII	4	2	12
IX	5	3	1
X	6	4	2
XI	7	5	3

In like manner, if you would inſert the ſeventh hour after the *Sun Riſing*: By the Table you ſee, that in the *Parallel* of VIII hours, for the length of the Day, the ſeventh hour from *Sun Riſing* is 3 in the afternoon; therefore obſerve where the hour-line of 3 croſſeth the *Parallel* of VIII hours, which is at *a*. —— Alſo by the Table you ſee that in the *Parallel* of XII hours, for

the length of the day, the ſeventh hour from *Sun-Riſing* is 1 in the Afternoon; wherefore obſerve where the hour-line of I croſſeth the *Equinoctial*, which is at *b*. —— Thirdly, By the Table you ſee, that in the *Parallel* of XVI hours, for the length of the Day, the ſeventh hour from the Sun's Riſing is 11 in the Forenoon; and therefore obſerve where the hour-line of XI croſſeth the *Parallel* of XVI hours, for the length of the day, which is at *c*; ſo ſhall a right-line, drawn through theſe three Points, *a*, *b*, *c*, be the ſeventh hour after the Sun's Riſing throughout the year: And thus by help of this little Table, may all the hour-lines from the Sun's Riſing be drawn as you ſee them drawn, and numbred, as in Fig. III.

In the ſame manner, as the hours from the Sun's Riſing (which are the *Babyloniſh* hours) were drawn, may the hours from the Sun's Setting (which are the *Italian* hours) be drawn: The difference being only in the numbering of them; the hours from Sun-Riſing being numbred from the *Weſt* end of the *Horizontal-line*, by 1, 2, 3, 4, 5, 6, 7, 8, 9, 10: And the hours from Sun-Setting from the *Eaſt* end of the *Horizontal-line* backwards, by 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13; all which is evident in the forenamed Fig. III.

COROLLARY.

The hour-lines from Sun-Riſing and Setting being deſcribed upon any Dial-Plain, as is before taught, there will by their correſpondent interſections one with another, be Points produced, through which if Lines be drawn with an even hand, the ſame ſhall be the *Parallels* of the Length of the Day, and ſuch are the Pricked Lines in Figure III, numbred upon the Meridian-Line of the *Dial*, by 8, 9, 10, 11, 12, 13, 14, 15, 16.

CHAP.

CHAP. IV.

Of the Jewiſh, *or Old* Unequal, *or* Planitary-hours, *and how they may be inſcribed upon any* Dial-Plain.

THe Ancients account of their day, was from the Sun's Riſing in the Morning, till it's Setting in the Evening, which ſpace of time they did divide into twelve equal Parts, were it long or ſhort: So that in the Summer all that time that the Sun hath *North-Declination*, the hours of their day were longer then a Common equal hour; and in the Winter, when the Sun hath *South-Declination*, the hours of their day were ſhorter than a common hour; but when the Sun is in the *Equinoctial*, their hours are equal to our Common hours.

The Inſcription of theſe hour-lines into all ſorts of Plains is very eaſie, being much like the Inſcription of the *Italian* and *Babyloniſh* hours, taught in the laſt Chapter.

Having

The Jewiſh,	The Parallel of 15 hours.		Equinoctial.	The Parallel of 9 hours.	
Hours	Ho.	Min.		Ho.	Min.
I	5	45	7	8	15
II	7	0	8	9	0
III	8	15	9	9	45
IV	9	30	10	10	30
V	10	45	11	11	15
VI	12	0	12	12	0
VII	1	15	1	0	45
VIII	2	30	2	1	30
IX	3	45	3	2	15
X	5	0	4	3	0
XI	6	15	5	3	45
XII	7	30	6	4	30

Having drawn your Dial, with hours, halfs, and quarters; and alſo the *Equinoctial*, the two *Tropicks*, and *Horizontal* Line; and alſo the *Parallels* of the length of the day, as is done in Figure VI, which is a *South* Dial declining *Eaſtward* 15 deg, you muſt make choice of two *Parallels* of the length of the Day, which muſt both of them be equidiſtant from the *Equinoctial*, which let be the *Parallels* of 9 hours, and 15 hours, for thoſe two *Parallels* are moſt convenient for this purpoſe; becauſe the *Jewiſh* hours in thoſe *Parallels* will juſtly fall upon the even hours, halfs, or quarters: Now the Points through which the *Jewiſh* hours are to be drawn, this Table will direct to; wherein you ſee, that the firſt *Jewiſh* hour is to be drawn through 5 hours, 45 min. in the *Parallel* of 15 hours, through 7 in the *Equinoctial*, and through 8 hours and 15 min. in the *Parallel* of 9 hours: ——In like manner the ſecond *Jewiſh* hour muſt be drawn through the interſection of the 7 hours in the *Parallel* of 15 hours, through 8 in the *Equinoctial*, and through 9 in the *Parallel* of 9 hours: And ſo muſt all the reſt of them be deſcribed as the Table does direct, and as you ſee done in Figure V. And in this manner, by help of this Table, may they be deſcribed in all ſorts of Plains, whither Direct, Reclining, or Declining.

CHAP.

CHAP. V.

How the Azimuths, *or* Vertical Circles, *are to be inſcribed upon* Dial Plains.

THe *Azimuths* are great Circles, and being Projected upon all Plains, become ſtreight Lines; and they are variouſly deſcribed, according as the Plain is ſituated; particulars of which follow.

SECT. I.

On an Horizontal *Plain.*

IN theſe Plains theſe *Azimuths* are moſt eaſily inſerted: For, your Dial being drawn, with the *Tropicks* and *Azimuths* thereupon, you have no more to doe, then upon the foot of the perpendicular Stile at O (in Figure VII) as a Centre, to deſcribe a Circle, as *S* ☌, *N* ☌, which you may divide into 32 equal Points (beginning at *N*) anſwering to the 32 Points of the Mariner's Compaſs, (or elſe you may divide it into 90 equal parts, or degrees,) noted with ***, &c. and through thoſe Points draw ſtreight Lines from O, the foot of the perpendicular Stile, and they ſhall be the true *Azimuths* upon the *Horizontal* Plain; which you may denominate by *South*, *S* by *E*, *S S E*, *S E* by *S*, &c. as you ſee done in Figure VII.

SECT.

SECT. II.

Upon an Erect, Direct East, *or* West *Plain, Figure I.*

HAving made an *East* Dial, and therein inſerted the *Equinoctial*, the two *Tropicks*, and the *Horizontal* Line, you may proceed to the Inſcription of the *Azimuths* in the manner following.

Upon the Point E, of the *Horizontal* Line of the Plain M E N, erect the Perpendicular E Q, equal to E G, (the height of the Stile of your Dial,) and upon Q, as a Centre, deſcribe the *Quadrant* Q E L, and divide it into eight equal parts, repreſenting one quarter of the Mariner's Compaſs, and from Q, through thoſe Points, draw Lines to the *Horizontal* Line M E N, noting them with ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ; from which Points let fall Perpendiculars from the *Horizontal* Line, and they ſhall be the *Azimuths* between the *South* and the *Eaſt* ; —— And for thoſe Points which fall between the *Eaſt* and the *North* ; namely *E* by *N*, —— *E N E*, —— *N E* by *N*, —— the ſame diſtances being ſet upon the *Horizontal* Line from E, towards the Left hand, as the three firſt *Azimuths*, *E* by *S*, —— *E S E*, —— *S E* by *E*, were towards the Right hand, ſhall give the three Points ⊙ ⊙ ⊙ on the Left hand of E ; through which Points alſo Lines drawn Perpendicular to the *Horizon*, ſhall be the *Azimuths*, or Points of the Compaſs between the *Eaſt* and the *North*: As in the Fig. I. And as the *Eaſt* Dial contains the *Azimuths* between the *South* and the *Eaſt* : The *Weſt* Dial muſt contain thoſe between the *South* and the *Weſt*.

SECT.

SECT. III.

Upon a direct South *upright Plain.* Figure *III.*

THe Dial, with the *Equinoctial*, the two *Tropicks*, and the *Horizontal* Line deſcribed thereon, the *Azimuths* may be inſerted thereon as followeth:

Firſt, Take the length of the *perpendicular Stile* of your Dial A B, and ſet it upon the *Meridian* of your Dial from B to G.

Secondly, With the diſtance G B, upon G, deſcribe the *Semicircle* E B F, which divide into 16 equal parts, (if you will,) but I have here divided it but into 8, to ſhew the manner of the Work, in the Points **** &c. through which Points from G, draw obſcure lines, extending them till they touch the *Horizontal* Line of the Plain C B D; now if from theſe Points of touching you draw lines *perpendicular* to the *Horizontal* Line between the *Tropicks*, or *Parallel*, to the line of 12, they ſhall be the *Azimuths* required.

I have not drawn the lines themſelves in this Fig. III. becauſe the Plain is full enough of Lines already.

SECT. IV.

Upon a South *Declining Plain.* Fig. VI.

AN Example ſhall be of a *South* Plain, declining Eaſtward 15 deg.

Such a Dial being drawn, and the *Equinoctial Tropicks*, and the *Horizontal* Line inſcribed thereon: Upon the

Point B of the *Horizontal* Line erect the *perpendicular* B C, equal to B O, the *perpendicular* Stile of your Dial; upon which Point C deſcribe the *Semicircle* R B S; which done, lay a Ruler to C, and the Point ☉, where the hour line of 12 croſſeth the *Horizontal* Line, and where the Ruler cuts the *Semi-circle* R B S, at that Point begin to divide it into 16 equal parts, at the Points *** &c. and from the Center C draw lines through thoſe Points, extending them till they touch the *Horizontal* Line D E, in the Points *a b c d e f g h i k* and *l*, through theſe Points right lines being drawn *Parallel* to the *Meridian*, ſhall be the *Azimuths* deſired, which you muſt number according to the ſituation of the Plain: Namely, the Weſtern *Azimuths* on the Eaſt ſide of the *Meridian*, and the *Eaſt Azimuths* on the *Weſt* ſide of the *Meridian*, as you ſee them numbred in Fig. VI.

CHAP. VI.

How to inſcribe the Circles of the Sun's Altitude into Dial-Plains.

THE *Almicanters*, or Circles of *Altitude*, in the *Sphere* have the ſame habitude to the *Azimuths*, or Vertical Circles, as the *Parallels* of declination have to the *Meridians*, or Hour-Circles: And therefore, the *Equinoctial* it ſelf, and all the *Parallels* of declination in a *Polar* Plain, and perfect Circles, and ſo are the *Almicanters*, or Circles of *Altitude*, upon an *Horizontal* Plain, as in Fig. VII.

Horizontal Plains, which lie *Parallel* to the *Horizon*, have the *Zenith* for their Poles: ſo that for the inſcription of them upon theſe Plains, the foot of the *perpendicular* Stile muſt be the Centre upon which to deſcribe them.

For

For the *Numeration* of theſe Circles when they are deſcribed, there are two ways moſt in Uſe: The one by Degrees and Minutes of the Sun's *Altitude*; the other according to the proportion that the height of any upright *Object* (as a Houſe, Steeple, &c.) bears to the ſhadow of it: The laſt of which I have here followed in this Figure VII. where the Circles of *Altitude* are equal, double, triple, and quadruple to the *Altitude* of the *perpendicular* Stile.

The inſcription of theſe Circles into all other Plains, are, in a kind, the ſame with the inſcription of the *Parallels* of Declination: Only, whereas in inſcribing of the *Tropicks*, and other *Parallels* of Declination, you take the Hour-lines out of the Dial-Plain, and put them into a *Trigon*; ſo in the inſcription of theſe you muſt take the *Azimuth* Circles out of your Plain, and put them into a *Trigon*, and from thence transfer them back again to your Plain, as in the other: And as the Hour-lines in the other, muſt be firſt drawn upon the Plain; ſo in this muſt the *Azimuths* be firſt inſcribed: And becauſe theſe Circles of *Altitude* are ſmaller Circles of the *Sphere*, as the *Tropicks* and *Parallels* of Declination were, they will upon all Plains (the *Horizontal* excepted) be *Conick* Sections.

CHAP. VII.

A General and Eaſie way to project Hour-lines upon all kind of Superficies, without any regard had to their ſtanding, either in reſpect of Declination, Reclination, or Inclination.

IF a Point be aſſigned upon any Superficies, Flat, or Curved, one or more, wherein the Hour-lines and *Axis* ſhall concur; how to project the Hours to that Point, and to ſet up an *Axis* after the ordinary manner to

give ſhadow to them, without any knowledge how the Dial ſtandeth in reſpect either of Reclination, Declination, or Inclination.

Firſt, To the Point aſſigned (upon any ſide of it) by help of a *Semi-circle*, or other Level, ſtretch out an *Horizontal* Thred, ſerving for the *Horizontal*-line; which line need not be one ſingle line, but may be turned at one or more Angles, provided that it lie (all the parts of it) totally in the Superficies of the *Horizon*.

Secondly, With a *perpendicular* thred held up, project the Sun into the aſſigned Point, and into the *Horizontal* thred, and ſtick in a Pin, or make a mark upon the ſame *Horizontal*-line, through which the ſhadow cutteth, and at the ſame inſtant alſo, take the Sun's *Altitude*.

Thirdly, By the *Altitude* taken find out the Sun's *Azimuth*; this *Azimuth*, what ever it be, is repreſented by the mark formerly made in the *Horizontal*-line or thred.

Fourthly, Apply a Paiſt-Board to the aſſigned Point, and hold it flat, that it may anſwer to the *Horizontal*-thred alſo; and upon this Paiſt-board protract your *Azimuth* by a thred extended from the Point aſſigned for the Centre to the mark upon the *Horizontal* thred. Which done,

Fifthly, By help of that *Azimuth* upon the Paiſt-board protract the *Meridian* Line, obſerving the true Coaſt, and quantity of the Angle from the *Azimuth*; and to the *Meridian* thus found, deſcribe an *Horizontal* Dial for the Place.

Sixthly, Apply the Paiſt-board to it's place again, all things ſtanding right as before; project all the Hours into the *Horizontal*-thred from off the Paiſt-board, and ſet marks upon the ſame Line; for the

the Points of each ſeveral Hour, which marks may be little Knots to ſlip too and fro upon the ſame thred.

Seventhly, Project the *Meridian* Point by a *perpendicular* Thred upon ſome Object, into that place whereabouts you imagine the *Axis* of the World would paſs, above or below, from the Point aſſigned for the Centre.

Eightly, With your *Semi-circle*, (or a String and Quadrant,) elevated or depreſſed, (as it ſhall be required,) from the Point aſſigned for the Centre, according to your Latitude, project the Pole of the World.

Ninthly, Extend a Thred from the Point aſſigned for the Centre to the Poles of the World, which ſhall repreſent the *Axis*.

Tenthly, By the Point upon the *Horizontal* Thred, and this *Axis*, (either by your Eye, laying the *Axis* to the Hour Points, or laying the Hour Knots to the *Axis*,) you may project all the Hours, and draw them:—— Or elſe you may let the *Axis* alone, and content your ſelf with the Pole point projected into the *Meridian*: For if from the Point aſſigned to be the Centre, or meeting of the Hours, and *Axis*, you extend a Thred to each Hour Point in the *Horizontal* Line, and do repoſe (with your Eye) the ſame Thred upon the Pole Points; then ſhall the ſhadow of the Thred give you that Hour-line; and do ſo in all the reſt.

Eleventhly, Your Thred, or *Axis* lying in it's true ſituation, you may eaſily fit an *Axis* to the ſame poſture. If your Dial be deſcribed upon a plain Superficies, you may then (by one ſide of a Square, applied to the Thred, or *Axis*, and the other ſide lying upon the Plain) find out the *Subſtile*, and meaſure from it the Elevation of the *Axis* above the Plain —— But

if

if the Dial be described upon a Curved Superficies, you must be content to set up your *Axis* by the direction of the Thred only.

Twelfthly, This point assigned for the Centre, being a Point of the *Axis*, is, as it were, the *Apex* of the *Griomon*, unto which all the Work is projected: But if it be required to set up an *Axis* to such a Superficies upon which the Hours and *Axis* will not meet in any tolerable manner, because perhaps the *Axis* may be but of very small Elevation above the Superficies, and yet an *Axis* is required, in this case set up any point (of Wire, or such like) of such distance from the Superficies, as that the Hours and *Axis* may be distinct, and through that point let it be required to make the *Axis* pass; you have no more to doe but only to project to this point as before, by letting the shadow of a *perpendicular* thred pass through that point, and noting the same upon the *Horizontal* thred, and counting that end of the Wire as your Centre, proceed as before; for the thred that lies to project the Hours is a pattern for the *Axis*.

This Way is general, serving to project the Hour-lines upon many Superficies, be they Plain or Curved, and however situate, whether contiguous or separate, and that without any laborious inquisition of any of their situations in respect of Declination, Reclination, or Inclination.

CHAP. VIII.

How from a Glass, Horizontally placed, to Reflect-hours upon any Superficies Flat or Curved, one or more.

First, The Glass being placed truly *Horizontal*, observe the spot of Light that the Sun casts, and make a Mark at it.

Secondly,

Secondly, And obſerve immediately the Sun's *Altitude*, and find the *Azimuth*.

Thirdly, Then extend an *Horizontal* thred in the ſame Level with the Glaſs, but within the Room.

Fourthly, Project the *Azimuth* into the *Horizontal* thred, by holding up a *perpendicular* thred in ſuch a place, that though it hang at liberty you may at once diſcern both the mark of the ſpot of Light and the Glaſs likewiſe; and then obſerve where the *perpendicular* thred ſeems to cut the *Horizontal* thred, and at that apparent interſection make a mark upon the *Horizontal* thred for the *Azimuth*.

Fifthly, Apply a Paiſt-board to the Glaſs, ſo that it may be ſtayed upon ſome reſt, that after it is taken away it may be reſtored to it's place again with all exactneſs: Let it be alſo placed Horizontally, ſo that it may have full relation to the *Horizontal* thred.

Sixthly, At the Glaſs's Centre make a point for the Centre upon the Paiſt-board, and extending a thred from the Centre of the Paiſt-board to the mark of the *Azimuth* upon the *Horizontal* thred, draw upon the Paiſt-board that line which the extended thred figures out thereupon; afterwards unto the ſame *Azimuth* upon the Paiſt-board draw a *Meridian* line, and to it an *Horizontal*-Dial; and applying the Paiſt-board again to it's firſt ſituation, project the hours thereon unto the *Horizontal* thred, and there make marks or knots.

Seventhly, Then project the *Meridian* (by a *perpendicular* thred, covering, in appearance, both the Knot at 12, and the Glaſs) unto the contrary Coaſt to that wherein the Pole is elevated above the *Horizon*; that is to ſay, in our Northern Climates, you muſt project the Meridian Southward from the Glaſs, becauſe the North Pole is elevated: And in the Meridian, elevate your *Semi-circle*, or extend a thred and quadrant from the Glaſs Southwards till the Plummet fall upon your Latitude, ſo ſhall it point out, upon ſome Object ſet to receive it, the North Pole reflected.

Or

Or elſe, if this be not convenient (becauſe in Windows which look towards the *South*, the *North* Pole will be without the Room, and ſo the *Axis* above the Glaſs extended towards that Pole will be without alſo) you may in ſuch Caſes find out the oppoſite Pole to it, that is to ſay, that Pole which the former reflected *Axis*, being extended through the Glaſs, and below it, would ſign out, and that may be effected in this manner.

Eighthly, Project the Meridian Line towards the Pole that is elevated, that is with us, towards the *North* Pole; and then (becauſe the *North* Pole is elevated by reflection towards the *South*, ſo, by the ſame reaſon, the *South* Pole muſt be depreſſed towards the *North*) by your *Semi-circle*, or ſtring and quadrant, directed even with the Centre of the Glaſs, expreſs or project your Latitude downwards, (but towards the *North*,) ſo ſhall the *Semi-circle*, or thred, point out the reflected *South* Pole in the Meridian. Now, whether you will, or can, (moſt conveniently,) uſe the reflected *North* Pole above the Glaſs, or the reflected *South* Pole below it, you are to take your Choice, for both the one, and the other of them do repreſent the reflected *Axis* of the World.

Ninthly, By this reflected *Axis*, and the Hour points ſigned out upon the *Horizontal* thred, you may eaſily Project the reflected Hours, upon any kind of Superficies, one or more, whatever they be, that ſtand in the way.

FINIS.